



Developing a Better Understanding of the Cost of CO₂ Transport and Storage: Moving Beyond a Fixed Storage Cost Assumption

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Presentation Objectives

- **Background**
- **Cost Analysis Methods**
- **Assumptions**
- **Factors affecting Cost**
 - **Reservoir Permeability**
 - **Reservoir Depth**
 - **Reservoir Thickness**
 - **Pipeline length/distribution network**
 - **Source size**
- **Conclusions**

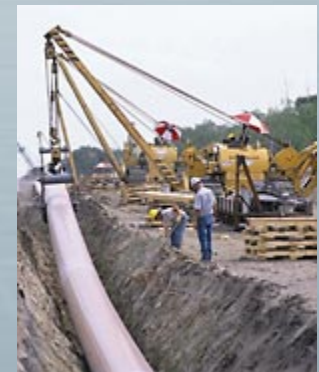
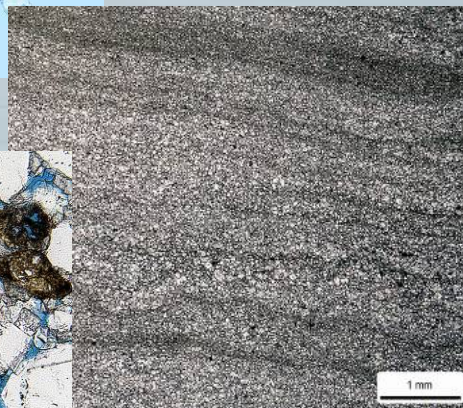
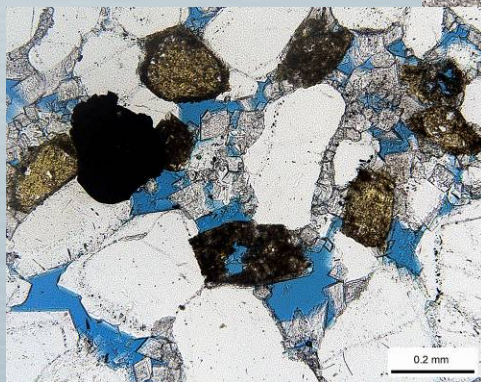
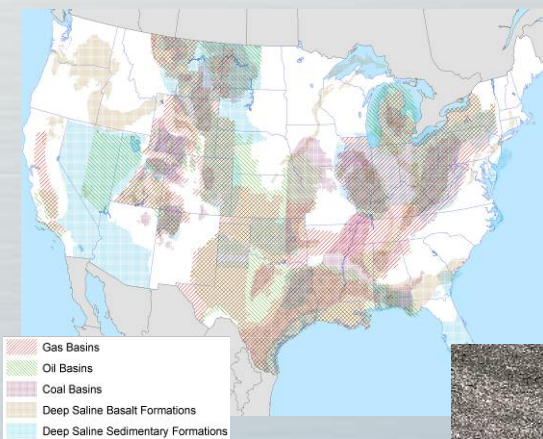


Background-

- **Considerable effort has gone into improving cost estimates for CO₂ capture / separation technologies and to better parameterize the operational characteristics of advanced energy systems such as IGCC+CCS.**
- **Comparatively less has been done to improve our understanding of the potential costs of transportation and storage (including MMV) for real world CCS systems and how those costs might vary.**
- **In the absence of this kind of information, many analyses continue to assume that the cost of CO₂ transport and storage is a small fixed charge that doesn't vary with time or from location to location.**

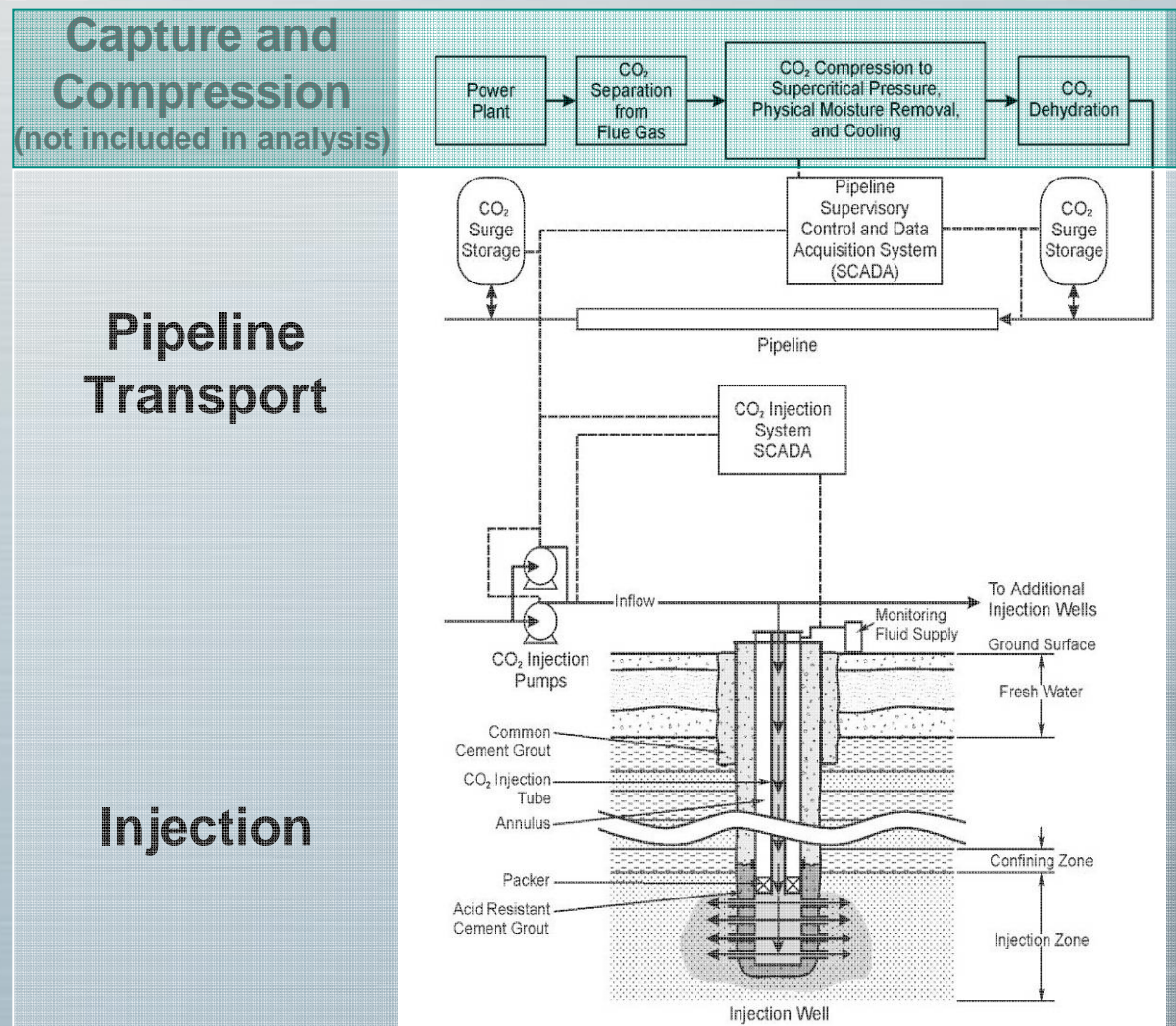
Background

- However, the cost of CO₂ transport and storage may vary with the source/sink location, nature of the storage target, surficial features, and other factors.



Research Goal is to Better Understand what Drives the Cost of CO₂ Transport and Storage

- Analysis is focused on costs associated with CO₂ transport, storage, MMV.
- Capture, separation and compression costs are not considered.
- Analysis includes cost of materials, services, design, operation, and maintenance.
- A “cost of capture” would need to be added to the costs shown here to derive a full CCS cost.



Methods

- ***Costs analyzed with Battelle proprietary estimator tool***
- Transport
 - Pipeline construction
 - Right-of-way
 - Booster stations
 - Operating and maintenance
- Injection/Sequestration
 - Preliminary Site Screening
 - Candidate Site Evaluation
 - Injection System Design
 - Injection System Construction
 - Injection System O&M



Units	# of units/yr	Item
kW-hr	53358468	Injection site electrical power cost
ea	29	Maintenance materials
ea	3	Maintenance staffing level
hr	6220	Maintenance labor
hr	122720	Operating labor
hr	2080	Supervisory labor
hr	1040	QA support
hr	1040	Health and safety support
ea	52	CO2 stream sampling&analysis
ea	4	Wireline, x-well, misc monitoring
events	4	USDW Monitoring
events	4	Leakage Monitoring
sqmi	1.4	3-D active seismic survey
ea	4	Reporting

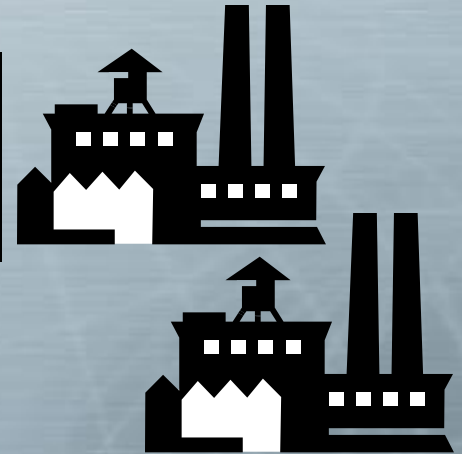
Methods – Source Streams

Two example source streams analyzed:

#1. 2.5 Million Metric Tons CO₂/Year
(~350 MW coal-fired power plant)

#2. 25 Million Metric Tons CO₂/Year
(~80,000 bbl/d coal-to-liquids facility)

- *These two initial source streams were selected as representative bookends of possible large commercial scale CCS facilities; examination of additional intermediate streams is planned.*

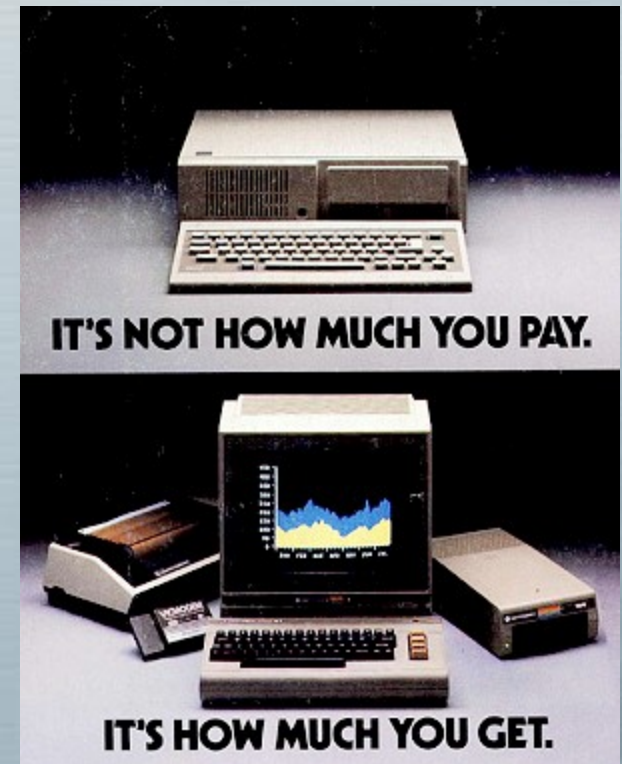


Assumptions

- Transport and Sequestration only analyzed. No CO₂ capture, separation, or compression.
- Assumes 25-year project lifespan for annualized costs.
- Injectivity assumed for different thickness and permeability:
 - Low permeability**- assumes ability to inject 600 metric tons CO₂/day per well in every 100 ft of effective reservoir thickness.
 - Medium permeability**- assumes ability to inject 1,500 metric tons CO₂/day per well in every 100 ft of effective reservoir thickness.
 - High permeability**- assumes ability to inject 3,000 metric tons CO₂/day per well in every 100 ft of effective reservoir thickness(injectivity based on general feasibility rather than analytical evaluation- 1,500 metric tons CO₂/day ~ 525,000 metric tons/year)
- Injectivities were selected to bound the representative range of values likely to be encountered by CCS project operators within onshore US

Key Cost Assumptions

- **Materials, labor etc. costs are circa 2000-2005**
 - **Since that time many of these costs have increased**
 - **Future research will include updating these costs**
 - **However, the general relationships established in the analysis should hold true**
- **25-year project lifespan for annualized costs**



Capital/Construction Costs

- **Capital Costs-**
 - Upfront construction costs, site screening, characterization, design, materials, etc.

Summary- Major Capital Cost Drivers

Pipeline	Injection System
<i>Installation/Construction</i>	<i>Well installation</i>
<i>Right-of-way access</i>	<i>Injection system, MMV system</i>
<i>Booster pumps, testing, monitoring system, etc.</i>	<i>Pipeline distribution, candidate evaluation, site screening, permitting, etc.</i>

Operating Costs

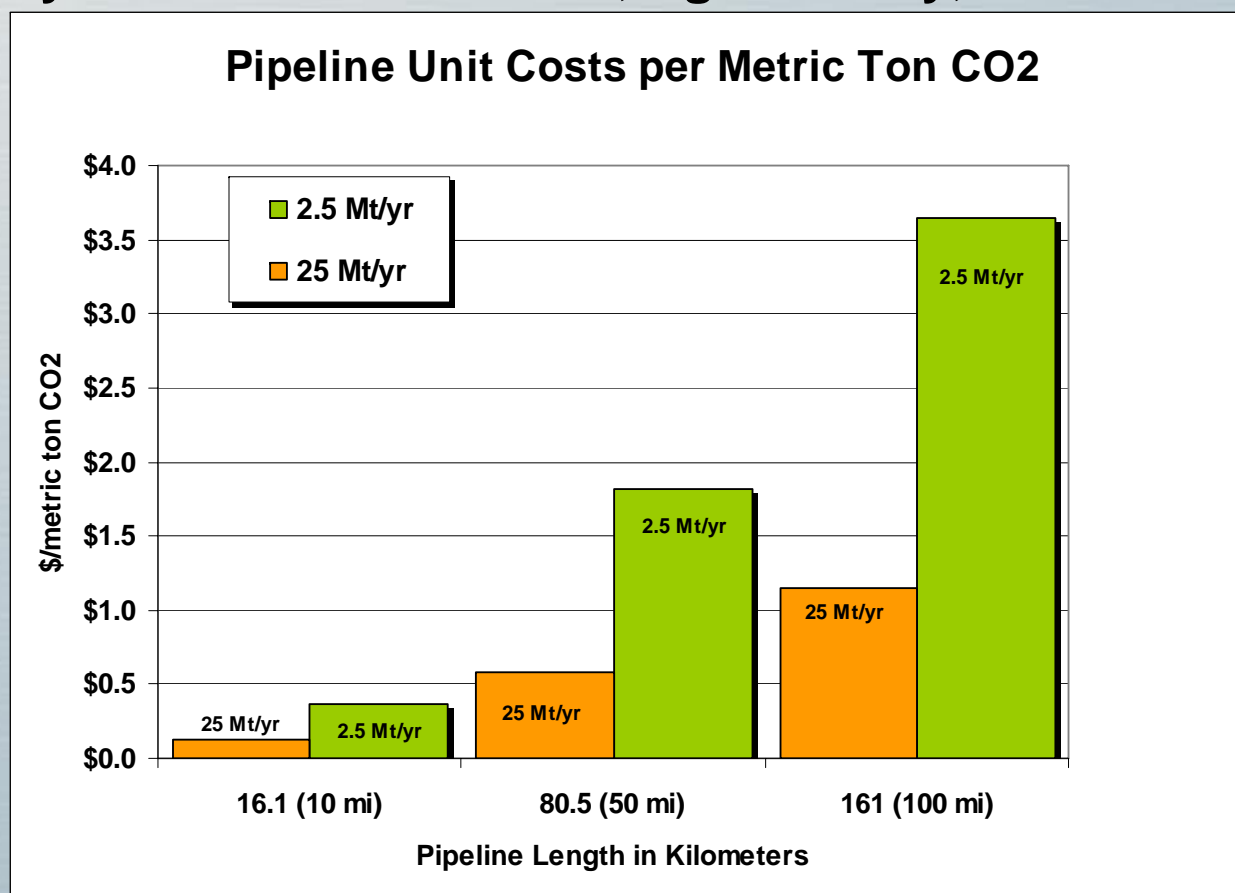
- **Operating Costs-**
 - Yearly operation and maintenance.
 - Includes power, staffing, replacement parts.
 - Generally lower than initial capital.

Summary- Major Operating Cost Drivers

Pipeline	Injection System
<i>Maintenance/Inspections/Monitoring</i>	<i>Maintenance, workovers, materials</i>
<i>Staffing</i>	<i>Power</i>
<i>Power (booster pumps, transmission)</i>	<i>MMV, permitting</i>

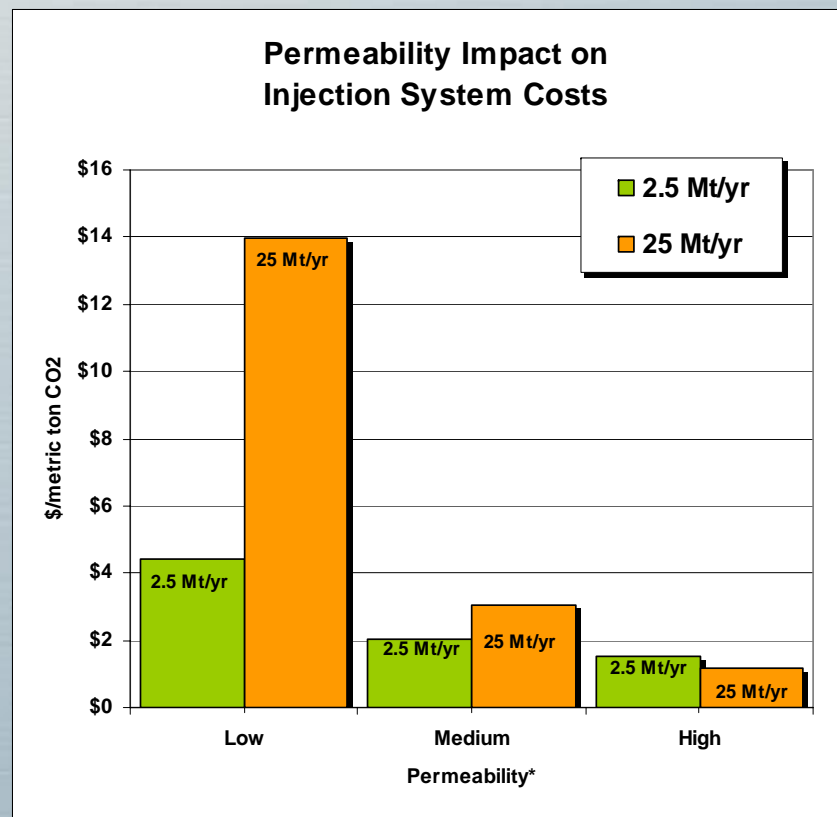
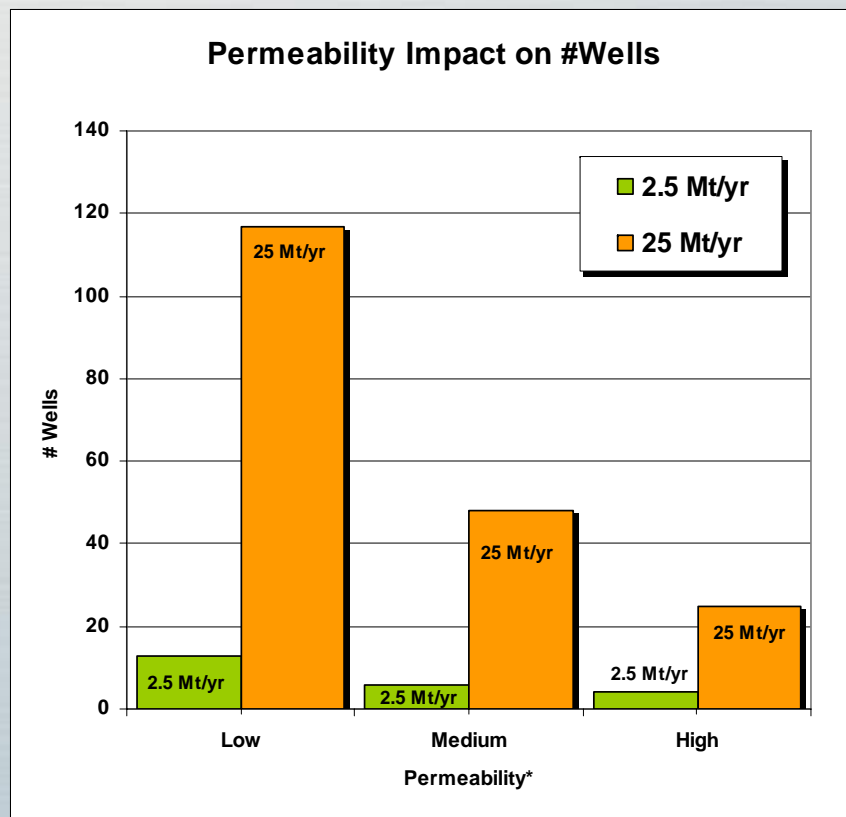
Pipeline Transport- Effect of System Size

- Long pipeline and small volume may be costly.
- Economies of scale in long pipeline and large volume system.
- Other analysis shows that terrain, right-of-way, climate affects costs.



Injection System Construction Cost Examples – Effect of Permeability

- Effects of reservoir permeability on injection system #wells and costs is mainly in the need for more wells, which also leads to larger footprint and field size



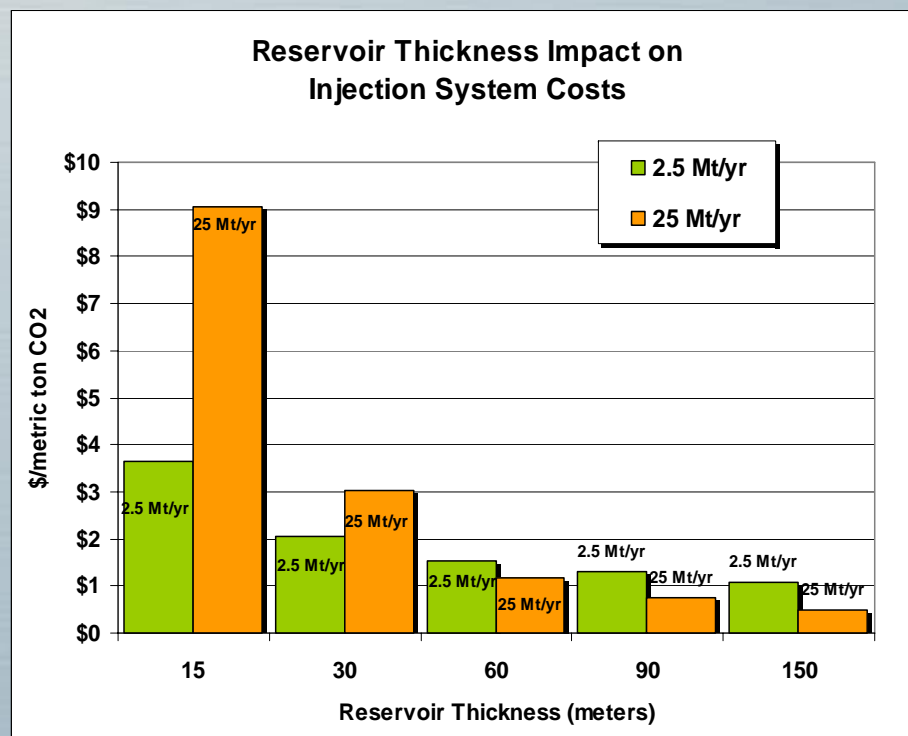
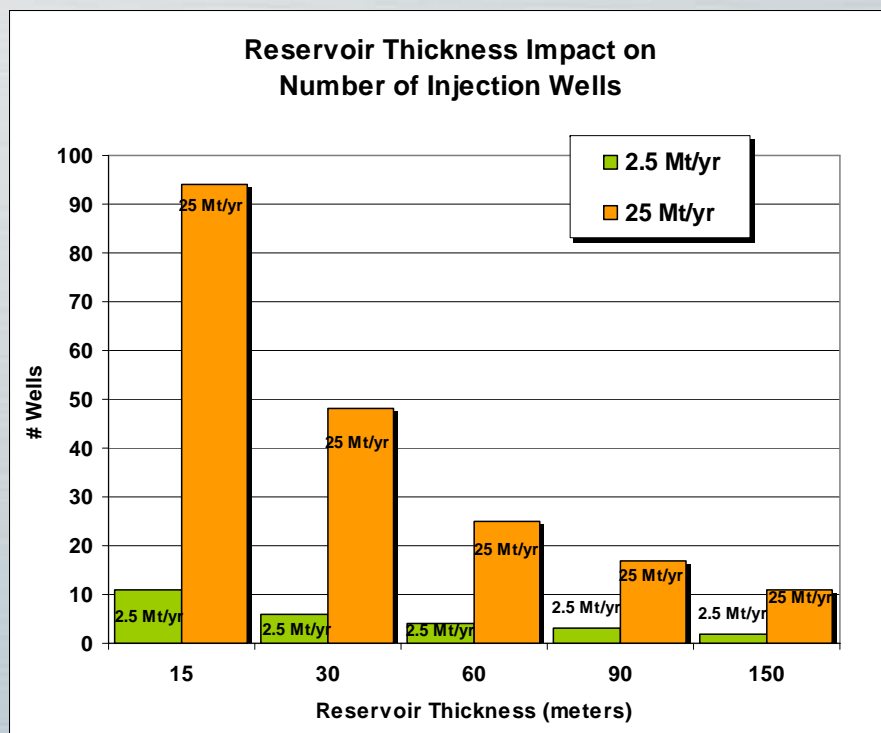
*Low = assumes ability to inject 220,000 metric tons CO₂/yr in each well at depth of 2000 m

Medium = assumes ability to inject 525,000 metric tons CO₂/yr in each well at depth of 2000 m

High = assumes ability to inject 1,000,000 metric tons CO₂/yr in each well at depth of 2000 m

Injection System Construction Cost Examples – Effect of Effective Thickness

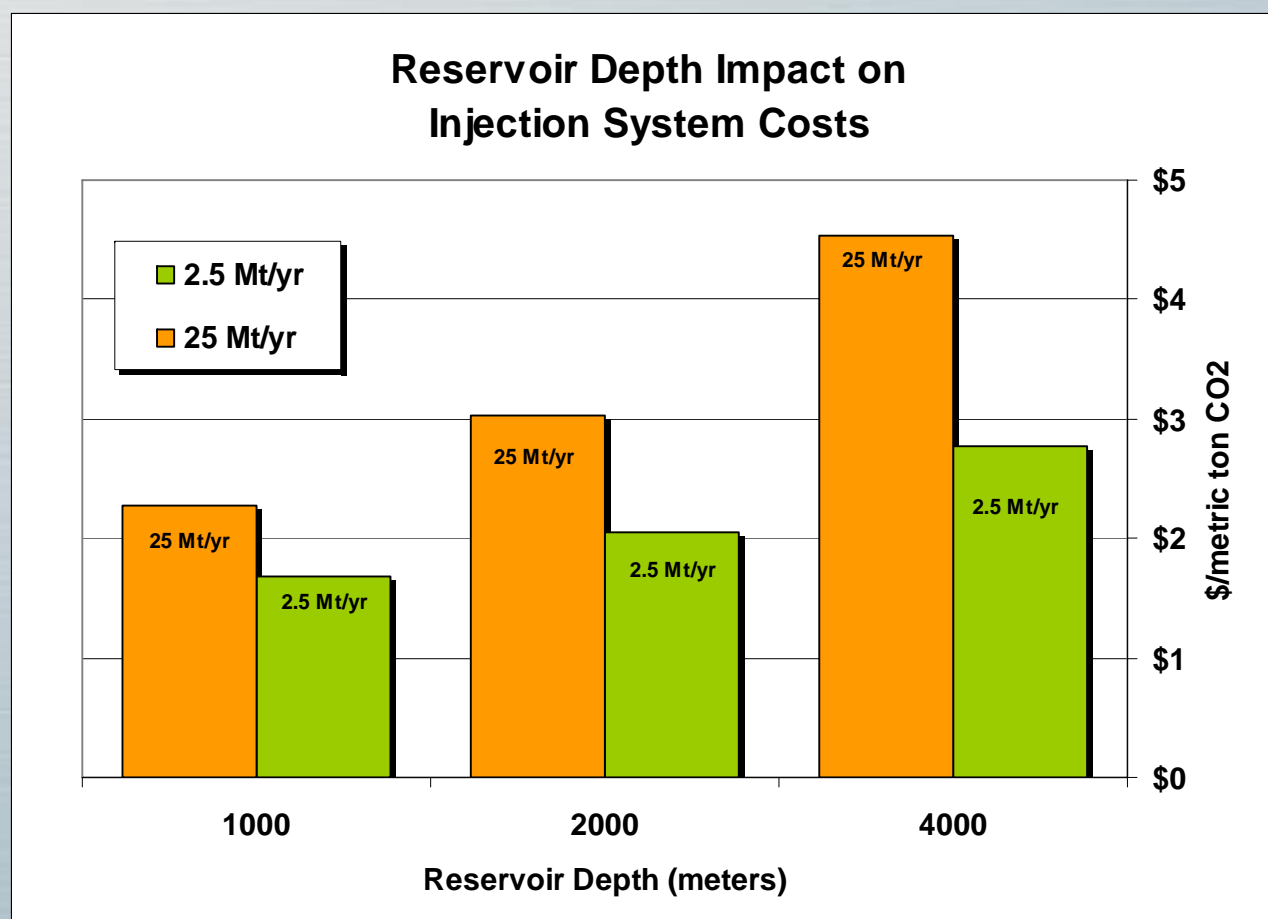
- Effects of decreasing effective reservoir thickness on injection system size and costs is mainly in the need for more wells, which leads to larger footprint
- Effective thickness and permeability are interrelated and both impact injectivity



a = assumes ability to inject 1,500 metric tons CO₂/day in every 100 ft of effective reservoir thickness

Injection System Construction Cost Examples – Effect of Reservoir Depth

- Deeper wells cost substantial higher due to complex design and capital costs
- Initial capital costs are distributed across life of the project, and operating costs are only slightly affected by well depths



Conclusions

- The cost of CO₂ pipeline transport ranged from \$0.12 and \$3.65 per metric ton CO₂.
- The smaller the size of the CO₂ point source the greater the incentive will be to site it as close as possible to its CO₂ storage reservoir.
- Conversely, at the cost of transport for very large CO₂ point sources is less sensitive to distance and therefore these facilities might have the ability to optimize their location between a CO₂ disposal formation and the markets / load centers they are serving.

Conclusions

- The cost of CO₂ storage (including MMV) ranged between \$0.48 to \$14.00 per metric ton CO₂.
- Costs were lowest when the reservoir was shallow (but at least 800m deep) and had high injectivity (a combination of large effective thickness and high permeability).
- The per ton cost for CO₂ storage for smaller CO₂ point sources appears to be more stable / robust across a fairly large range of potential candidate CO₂ storage formations.
- On the other hand, larger CO₂ point sources will likely place a higher value / invest more effort in locating near high quality CO₂ storage reservoirs.
- The number of injector wells may vary from 2-100.

Conclusions

- Analysis of the significant infrastructure needed to store large volumes of CO₂ suggests significant and highly variable costs for transport and storage that must be taken into account in modeled CCS deployment scenarios.
- Economies of scale come into play with larger projects.
- Some economic analysis may be worthwhile to minimize costs associated with long transport distances or large well fields.
- There may be opportunity to reduce costs by combining pipeline and injection system items (ex. System monitoring).

Path Forward

- Maintain and update cost estimator tool based on developments in CCS.
- Validate costs with ongoing projects.
- Integrate model with better estimates on injectivity and basin specific items.



The End

